Biologically Inspired Computing

EECS 6180

Homework 5

Hopfield Networks

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Mar. 22, 2012

Max. Pts 20

Use 1, -1 for black white

1. Design a Hopfield Neural Network to recognize the following two patterns.

a. Describe the network architecture. How many neurons will it require? 5pts

This network will require as many neurons as there are pixels [16 neurons for 16 pixels]. The neurons will each have weight values representing the connections to all other neurons this will require each of the 16 neurons having 16 weights for a total number of 16^2 weights = 256 weights.

b. Calculate the weight matrix. 5pts

The weight matrix W is calculated using the following formula:

$$W = \sum_{m=1}^{M} Y_m Y_m^T - M * I$$

Where M is the total number of states (images) needed to be memorized and I is the identity matrix.

For calculating the weight matrix both patterns were made into a single row matrix so:

P1 = Patter 1 = [1 1 1 1 1 -1 -1 1 1 -1 -1 1 1 1 1 1]

P2 = Pattern 2 = [1 -1 -1 1 -1 1 1 -1 -1 1 1 -1 1 -1 -1 1]

%in matlab

```
P1 = [1 1 1 1 1 -1 -1 1 1 -1 -1 1 1 1 1 1];
P1t = P1';

P2 = [1 -1 -1 1 -1 1 1 -1 -1 1 1 -1 1 -1 -1 1];
P2t = P2';

Y1 = P1t*P1;
Y2 = P2t*P2;

W = Y1 + Y2 - 2*eye(16)=
```

0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	2
0	0	2	0	2	-2	-2	2	2	-2	-2	2	0	2	2	0
0	2	0	0	2	-2	-2	2	2	-2	-2	2	0	2	2	0
2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
0	2	2	0	0	-2	-2	2	2	-2	-2	2	0	2	2	0
0	-2	-2	0	-2	0	2	-2	-2	2	2	-2	0	-2	-2	0
0	-2	-2	0	-2	2	0	-2	-2	2	2	-2	0	-2	-2	0
0	2	2	0	2	-2	-2	0	2	-2	-2	2	0	2	2	0
0	2	2	0	2	-2	-2	2	0	-2	-2	2	0	2	2	0
0	-2	-2	0	-2	2	2	-2	-2	0	2	-2	0	-2	-2	0
0	-2	-2	0	-2	2	2	-2	-2	2	0	-2	0	-2	-2	0
0	2	2	0	2	-2	-2	2	2	-2	-2	0	0	2	2	0
2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
0	2	2	0	2	-2	-2	2	2	-2	-2	2	0	0	2	0
0	2	2	0	2	-2	-2	2	2	-2	-2	2	0	2	0	0
2	0	0	2	0	0	0	0	0	0	0	0	2	0	0	0

c. Test if these two patterns are classified correctly with that weight matrix. 5pts

Testing Pattern1 with W:

```
%test P1
testP1 = W*P1t;

%sign function
for i = 1:length(testP1)
    if testP1(i) > 0
        testP1(i) = 1;
    elseif testP1(i) < 0
        testP1(i) = -1;
    else
        testP1(i) = 0;
    end
end
```

testP1' =

```
 1  1  1  1  1 -1 -1  1  1 -1 -1  1  1  1  1  1
```

P1 =

```
 1  1  1  1  1 -1 -1  1  1 -1 -1  1  1  1  1  1
```

W works for Pattern 1 recognition

Testing Pattern2 with W:

```
%test second original image
testP2 = W*P2t;

%sign function
for i = 1:length(testP2)
    if testP2(i) > 0
        testP2(i) = 1;
    elseif testP2(i) < 0
        testP2(i) = -1;
    else
        testP2(i) = 0;
    end
end
```

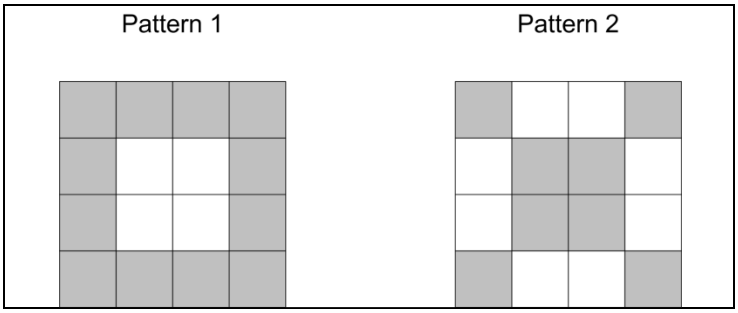
testP2' =

```
  1  -1  -1   1  -1   1   1  -1  -1   1   1  -1   1  -1  -1   1
```

P2=

```
  1  -1  -1   1  -1   1   1  -1  -1   1   1  -1   1  -1  -1   1
```

W works for Pattern 2 recognition



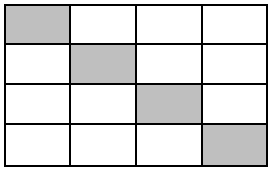


Fig. 2

d. If a new pattern is given as shown in Fig. 2, to which category it will be classified? 5pts

Testing figure 2 for recognition to Pattern 2 or Patter 1

For this test figure 2 was made into a row matrix in MATLAB:

```
fig2 = [1 -1 -1 -1 -1 1 -1 -1 -1 -1 1 -1 -1 -1 -1 1];
fig2mat = vec2mat(fig2,4)
fig2 = fig2';

testfig2 = W*fig2;
test2mat = vec2mat(testfig2, 4)

fig2mat =

     1    -1    -1    -1
    -1     1    -1    -1
    -1    -1     1    -1
    -1    -1    -1     1


test2mat =

    -2   -14   -14     2
   -14    14    18   -14
   -14    18    14   -14
     2   -14   -14    -2

% for iterations until conferging to a pattern
%check sign of pixels
for i = 1:length(testfig2)
    if testfig2(i) > 0
        testfig2(i) = 1;
    elseif testfig2(i) < 0
        testfig2(i) = -1;
    else
        testfig2(i) = 0;
    end
end

resultmat = vec2mat(testfig2,4)
testfig2 = W*testfig2;
```

Iteration 1: resultmat =

-1	-1	-1	1
-1	1	1	-1
-1	1	1	-1
1	-1	-1	-1

Iteration 2: resultmat =

1	-1	-1	-1
-1	1	1	-1
-1	1	1	-1
-1	-1	-1	1

Iteration 3: resultmat =

-1	-1	-1	1
-1	1	1	-1
-1	1	1	-1
1	-1	-1	-1

Iteration 4: resultmat =

1	-1	-1	-1
-1	1	1	-1
-1	1	1	-1
-1	-1	-1	1

Iteration 5: resultmat =

-1	-1	-1	1
-1	1	1	-1
-1	1	1	-1
1	-1	-1	-1

Iteration 6: resultmat =

1	-1	-1	-1
-1	1	1	-1
-1	1	1	-1
-1	-1	-1	1

Iteration 7: resultmat =

-1	-1	-1	1
-1	1	1	-1
-1	1	1	-1
1	-1	-1	-1

Iteration 8: resultmat =

1	-1	-1	-1
-1	1	1	-1
-1	1	1	-1
-1	-1	-1	1

After at 8 iterations of the sign check it seems that the network would converge to choosing Patter2 for figure 2. This will NOT be an exact match.